RESTRAINT SYSTEM WITH IMPACT RECOGNITION, TAKING INTO ACCOUNT ENVIRONMENTAL INFLUENCES

Description

The present invention relates first of all to a method for operating an internal combustion engine, in which a quantity of fuel arriving in a combustion chamber is a function of the triggering of a piezo actuator of a fuel injector, whose triggering

5   energy is made available by a buffer store.

Such a method is known from EP 1 138 917 A1. It describes a fuel injection system of an internal combustion engine, which includes a piezo actuator. It is used to control the fuel quantity to be injected. This is accomplished in that the piezo actuator is

10   charged and discharged by a driver circuit. Due to the charging, the piezo actuator expands and moves a valve element coupled to it. Upon discharge, the piezo actuator shortens again.

The energy for charging the piezo actuator is made available by a buffer capacitor. It

15   is recharged by a direct current source. The energy flowing away from the piezo actuator when being discharged is fed back into the buffer capacitor.

Therefore, the object of the present invention is to further develop a method of the type indicated at the outset in such a way that it is possible to easily and reliably

20   monitor the correct functioning of the injection system.
This objective is achieved in a method of the type indicated at the outset, in that, at least intermittently, the potential difference of the buffer store resulting in response to a triggering of the piezo actuator is at least approximately ascertained and used for a comparison to at least one limiting value.

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Summary of the Invention
Using the present invention, it is possible to monitor the correct functioning of the fuel injection system permanently and without additional expenditure. This is accomplished by monitoring the triggering, thus the charging and discharging of the

30   piezo actuator. The piezo actuator is a central part of the fuel injection system, for it

ultimately sets the quantity of fuel arriving in the combustion chamber. Its correct functioning is thus of prime importance for the entire fuel injection system.

The present invention is based on the idea that it is possible to monitor the operation of the piezo actuator very well by detecting the electrical energy transmitted to or released by the piezo actuator in response to a triggering. The basis for this, in turn, is that, unlike a magnet actuator, for instance, a piezo actuator is only triggered for the actual change in length, whereas in the stationary state of the piezo actuator, no electrical energy flows. Usually, electrical energy is supplied to the piezo actuator to increase its length, and electrical energy stored in it is led away again to shorten its length.

The electrical energy supplied to the piezo actuator for an actuation is made available by a buffer store, and in response to a corresponding actuation of the piezo actuator, the electrical energy is returned to this buffer store again. The buffer store is usually a buffer capacitor. Because the electric charge of the buffer store is recorded before and after a triggering of the piezo actuator, the electrical energy actually supplied to or actually removed from the piezo actuator may be determined with excellent accuracy. The ascertained electrical energy is then compared to a setpoint or limiting value. In this way, the performance reliability of the piezo actuator may be evaluated quickly, easily, and during the operation of the fuel injection system.

Advantageous further developments of the present invention are set forth in the dependent claims.

According to a first refinement, an electrical energy, with which the buffer store is charged between the moments of ascertaining its potential, is determined and taken into account when ascertaining an electric charge actually exchanged between the piezo actuator and the buffer store. The buffer store is generally fed by a DC/DC converter. This DC/DC converter optionally recharges the buffer store in the time between the measurements. The electrical energy actually released to the piezo actuator or which has flowed back from it may therefore be ascertained with even greater accuracy if the electrical energy which has optionally flowed from the DC/DC

converter to the buffer store is taken into account when ascertaining the potential difference of the buffer store resulting from the triggering of the piezo actuator.

To that end, in a specific embodiment, it is proposed that the energy with which the buffer store is charged be added to or subtracted from the potential difference, and that the addition result or the subtraction result be used for the comparison to the at least one limiting value.

A method easy to implement from the standpoint of programming technology is one in which the energy with which the buffer store is charged is estimated with reference to a program map into which a supply current and a time duration between the two ascertainments of the buffer-store potential are fed.

Alternatively, it is also possible to deactivate a charge of the buffer store for determining the buffer store. This is possible from time to time when the buffer store has a sufficiently high capacitance. In this case, it is possible to dispense with the programming of a program map, for instance, and precise results are nevertheless attained.

It is particularly preferable if, when the potential difference of the piezo actuator is equal to or greater than a first limiting value, an error entry corresponding to a short circuit is made and/or an action is initiated corresponding to a short circuit. This is based on the idea that, in the event of a short circuit, in addition to the charging current or discharging current, another current is flowing via the specific short-circuit path. Therefore, the buffer store or the piezo actuator discharges more strongly than in the normal case, and the difference of the detected potentials is then at least equal to or greater than the first limiting value. Using this method, it is thus not only possible to recognize a malfunction per se, but the malfunction may also be qualified.

In a further development of this, it is proposed that when the potential difference of the piezo actuator is equal to or less than the first limiting value and equal to or less than a second limiting value, an error entry is made corresponding to a load drop and/or an action is initiated corresponding to a load drop. Using the method of the present invention, it is thus possible to distinguish between different error causes,

which has considerable advantages with regard to the measures to be taken in the event of an error.

The invention starts from the assumption that in the event of a load drop, ultimately no current flows in response to a triggering of the piezo actuator, so that the voltage of the buffer store does not change, or at least does not change significantly. The difference between the two recorded potentials of the buffer store (before and after a triggering of the piezo actuator) therefore lies below this limiting value.

The present invention also relates to a computer program that is suited for implementing the above method when it is executed on a computer. In this context, it is particularly preferred for the computer program to be stored in a memory, particularly in a flash memory.

The subject matter of the present invention is also a control and/or regulating device for operating an internal combustion engine. It is especially preferred if it includes a memory in which a computer program as recited in one of Claims 8 or 9 is stored. The present invention moreover relates to an internal combustion engine having a control and/or regulating device of the type indicated above.

Brief Description of the Drawing

An especially preferred exemplary embodiment of the present invention is explained in detail in the following with reference to the accompanying drawing. The figures show:

Figure 1   a schematic representation of a fuel system having a plurality of fuel injectors designed according to a first particular embodiment;

Figure 2   a partial section through one of the fuel injectors from Figure 1;

Figure 3   a block diagram of a method for operating the fuel system of Figure 1;

Figure 4   a flow chart corresponding to the block diagram of Figure 3;

Figure 5   a section through another particular embodiment of a fuel injector.

Description of the Exemplary Embodiment

In Figure 1, an entire fuel system is designated by reference numeral 10. It includes a fuel tank 12, from which an electric fuel pump 14 delivers the fuel to a high-pressure

fuel pump 16. It feeds a fuel collection line 18 (rail), in which the fuel is stored under high pressure.

Connected to fuel collection line 18 are a plurality of fuel injectors 20. They inject the
5   fuel directly into combustion chambers 22 of an internal combustion engine (not further shown). The fuel injectors are triggered by a control and regulating device 24.

The design of a fuel injector 20 is shown in Figure 2. According to that, fuel injector 20 includes a housing 26 having a blind-end stepped bore hole 28. Positioned at its
10   upper end is a piezo actuator 30 connected to a piston 32. Piston 32 delimits a working chamber 34 of a hydraulic converter. Part of the hydraulic converter is also a piston 36 which is connected to a spherical valve element 38. Piston 36 has a smaller diameter than piston 32 and is tightly guided in the housing.

15   Valve element 38 cooperates with an upper valve seat 40 in Figure 2, and with a lower valve seat 42 in Figure 2. Valve seats 40 and 42 regionally border a cavity 44, which is connected via a throttle (without reference numeral) to a control chamber 46. It, in turn, is connected via a throttle (without reference numeral) and a pressure line 47 to fuel collection line 18. Control chamber 46 in Figure 2 is bounded toward the
20   bottom by a valve needle 48. A duct 50 connects fuel collection line 18 to a pressure chamber (not visible) in the region of the lower end of valve needle 48.

Fuel injector 20 operates in the following manner: Piezo actuator 30 may be charged and discharged again via a device explained in greater detail below. The longitudinal
25   extension of piezo actuator 30 is shorter in the discharged state than in the charged state. For the sake of simplicity, hereinafter the state having the shorter longitudinal extension is known as "short", and the state having the maximum longitudinal extension is known as "long.".

30   When piezo actuator 30 is in its short or long state, valve element 38 rests on valve seat 40 or on valve seat 42. In both cases, the hydraulic pressure transmitted from fuel collection line 18 via pressure line 47 into control chamber 46 holds valve needle 48 in its closed position. Therefore, no fuel is able to escape from fuel injector 20.

However, if piezo actuator 30 is triggered so that it moves either from its short position into the long position, or from the long position into the short position, valve element 38 rests neither on valve seat 40 nor on valve seat 42. This leads to a pressure drop in control chamber 46, and ultimately to a pressure difference between the upper end and the lower end of valve needle 48. The valve needle in Figure 2 subsequently moves upward and releases the path for the fuel out of duct 50. Thus, fuel is able to emerge from fuel injector 20 into corresponding combustion chamber 22.

Piezo actuator 30 is triggered by an electronic circuit 52, a few components of which are shown in Figure 2. A voltage source 54 provides a DC voltage which is converted in a DC/DC converter 56 according to the specific requirements. The electrical energy made available by DC/DC converter 56 charges a capacitor 58. It functions as a buffer store for the electrical energy to be supplied to or carried away from piezo actuator 30. Capacitor 58 may be connected to piezo actuator 30 via a charging switch 60 and a discharging switch 62. The electrical charge stored in capacitor 58 is measured by a measuring circuit 64.

In the quiescent state, both charging switch 60 and discharging switch 62 are open; thus no current flows between piezo actuator 30 and buffer capacitor 58. In order to bring piezo actuator 30 from its short state into the long state, it must be electrically charged. To that end, charging switch 60 is closed. Discharging switch 62 remains open. Current therefore flows from buffer capacitor 58 to piezo actuator 30. As soon as piezo actuator 30 has reached the desired end position, charging switch 60 again remains open.

To bring piezo actuator 30 from the long into the short position, the electrical charge present in piezo actuator 30 must be carried away again. For that purpose, with charging switch 30 open, discharging switch 62 is closed. In this way, the electrical charge stored in piezo actuator 30 is returned to capacitor 58.

Of course, charging switch 60 and discharging switch 62 are not usually closed constantly during an actuation, but rather are closed only for a short period and then opened again, the charge state of piezo actuator 30 then being registered and charging switch 60 or discharging switch 62 possibly being closed again for a short period.

This process is repeated until piezo actuator 30 has received the desired charge or released the charge again. The details regarding this are described in EP 1 138 917 A1, to which reference is specifically hereby made.

5   To be able to monitor the triggering of piezo actuator 30, one proceeds according to the method presented in Figures 3 and 4: Measuring circuit 64 measures the charge state of buffer capacitor 58 prior to a triggering (reference numeral 66) and after a triggering (reference numeral 68). In this context, the term "triggering" is intended to mean a charging of piezo actuator 30 and a corresponding discharging of buffer

10   capacitor 58, or else a discharging of piezo actuator 30 and a corresponding charging of buffer capacitor 58. Difference dU1 between the measured values before and after the triggering is formed in 70.

In 72, a correction value is added to difference dU1 determined in 70. This correction

15   value is determined with the aid of a program map 74 into which is fed, on one hand, the time between the two measurements (reference numerals 66 and 68), and on the other hand, the current discharged from the DC/DC converter to buffer capacitor 58. Therefore, potential difference dU2 resulting from block 72 corresponds to the energy actually discharged from buffer capacitor 58 to piezo actuator 30 or returned from

20   piezo actuator 30 to buffer capacitor 58. Namely, using program map 74, it is taken into account that buffer capacitor 58 is recharged by DC/DC converter 56 in the period of time between the registering of the potential of buffer capacitor 58 prior to a triggering and the registering of the potential after a triggering.

25   Potential difference dU2 is fed into a first comparator 76, in which potential difference dU2 is compared to an upper threshold value. If potential difference dU2 is above this upper threshold value, this means that more current is flowing back and forth between buffer capacitor 58 and piezo actuator 30 than is to be expected in the normal case. This is an indication of a short circuit, since in this case, in addition to

30   the normal charging current, another current is flowing via the corresponding short-circuit path. A corresponding error entry and/or an action (e.g. switching off the triggering of individual cylinders or the entire system) is then carried out. The corresponding block bears reference numeral 78 in Figure 1.

Potential difference dU2 is also fed into a second comparator 80 and compared there to a lower threshold value. If potential difference dU2 is less than the lower threshold value, this is an indication of a load drop. Namely, in this case, no current flows from capacitor 58 to piezo actuator 30 or back in response to the triggering of piezo

5 actuator 30; thus, the voltage of buffer capacitor 58 does not change or at least does not change significantly. A corresponding error entry and a corresponding action are then carried out (block 82).

Figure 5 depicts a further embodiment of a fuel injector. Those elements and regions

10 which have functions equivalent to elements of the fuel injector shown in Figure 2 bear the same reference numerals and are not described again in detail.

In contrast to the fuel injector of Figure 2, that of Figure 5 is not a double switching type, but rather a single switching type. That is to say, valve element 38 rests on a

15 valve seat 40 only in one switching position. When it lifts off of valve seat 40, it blocks a fluid bypass duct 84 situated between a high-pressure region 47 and cavity 44 (this state is shown in Figure 5). Therefore, the pressure in cavity 44 drops via a low-pressure duct 88, and also in control chamber 46 via a restrictor duct 86, resulting in a corresponding opening movement of valve needle 48.

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When valve element 38 comes to rest again on valve seat 40, the connection of cavity 44 to low-pressure region 88 is interrupted again, and bypass line 84 is again released. The pressure in cavity 44 thereby rises again to the high-pressure level (region 47). Control chamber 46 is charged to the high-pressure level comparatively efficiently on

25 one hand through restrictor duct 86 between cavity 44 and control chamber 46, and on the other hand by a fluid restrictor duct 90 situated between high-pressure region 47 and control chamber 46.